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ORIGINAL RESEARCH

THE EFFECT OF FATIGUE ON UPPER QUARTER Y-BALANCE TEST SCORES IN RECREATIONAL WEIGHTLIFTERS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: A paucity of research currently exists for upper extremity return to sport testing. The Upper Quarter Y-Balance Test (YBT-UQ) is a clinical test of closed kinetic chain performance with demonstrated reliability. Prior investigations of the YBT-UQ were conducted with individuals in a resting state and no comparison to performance in a fatigued state has been conducted.

Purpose: To examine the effect of upper extremity fatigue on the performance of the YBT-UQ in recreational weightlifters.

Study Design: Randomized controlled trial

Methods: 24 participants who participated in recreational weight training three days per week were randomly allocated to a control or experimental group. Individuals in the control group were tested using the YBT-UQ and re-tested after a 20-minute rest period. Participants in the experimental group were tested with the YBT-UQ, performed an upper extremity exercise fatigue protocol, and immediately re-tested. Examiners were blinded to participant allocation.

Results: Differences from pre- to post-fatigue YBT-UQ testing revealed score reductions between 2.04cm – 12.16cm for both composite scores and individual reach directions. The repeated measures ANOVA revealed significant differences when comparing the pre- and post-testing results between the fatigue and non-fatigue groups for all individual directions ($p \leq .006$) and composite scores both limbs ($p < .035$).

Conclusion: The performance of an upper body fatigue protocol significantly reduces YBT-UQ scores in recreational weightlifters.

Level of Evidence: 1b

Keywords: Fatigue, functional testing, upper extremity, Upper Quarter Y-Balance Test

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INTRODUCTION

Resistance training is a popular form of exercise for both athletic and recreational purposes. Injury resulting in medical attention as a result of resistance training, has been reported at a prevalence between 25-30%.[1] The shoulder complex is a common region for exercise related injury, comprising 36% of all incidents.[1] Shoulder injury often results in reduced strength, proprioception, and balance which can be assessed with both open or closed chain testing.

Two common tests used to evaluate the upper extremity include the closed kinetic chain upper extremity stability test (CKC-UEST) and the one-arm hop test.[2-4] The CKC-UEST requires participants to assume an upright push-up position with their feet 36 inches apart. The test then scores how many times an individual can reach across midline to the contralateral hand while maintaining the push-up position. The CKC-UEST has been shown to be reliable and predictive of injury, but only assesses the upper extremity in a single plane and does not differentiate performance for a single limb.[2,3] The one-arm hop test, has also been shown to be reliable, but only measures single arm power.[4] More recently, the Upper Quarter Y-Balance Test (YBT-UQ), a clinical test of closed kinetic chain performance, has demonstrated high reliability for assessment of unilateral upper extremity function.[5] The YBT-UQ has also demonstrated the ability to serve as a measure for normal function when testing an injured upper extremity with reported similarity between dominant and non-dominant limbs.[6]

The clinical tests described previously are commonly used by physical therapists to assess upper extremity performance, but individuals are typically tested in a non-fatigued state. Fatigue is defined as a transient decrease in the capacity to perform physical actions[7] and can result in a reduction in muscle force, impaired coordination, delayed neuromuscular activation, and impaired joint stability.[8-13] These fatigue induced impairments could result in greater injury risk in both athletic and recreational activities. To date, a paucity of research exists investigating the performance of the YBT-UQ under fatigue. The purpose of this investigation was to examine the effect of muscular fatigue on YBT-UQ scores in recreational weightlifters. The hypothesis was that YBT-UQ performance would decline in participants tested in a fatigued state.[11-13]

METHODS

Study Design

This study was a prospective randomized controlled trial. The study flow diagram is outlined in Figure 1. Twenty-four healthy, college-aged subjects were recruited from a local university community with publicly displayed flyers. Participants were provided explanation of testing procedures and gave written informed consent prior to testing. Participants were included in the study if they performed upper-extremity resistance weight training on average three days per week (range 2-5), possessed sufficient ability to read English as required for completing questionnaires, and were over 18 years of age. Exclusion criteria consisted of any single red flag item noted in the patient's medical screening questionnaire, answered yes to any question on the physical activity readiness questionnaire (PAR-Q), prior surgical history on either left or right upper extremity and currently experiencing pain in either the left or right upper extremity. The Institutional Review Board approved the study protocol.

Participants

Twenty-four participants (mean age 25.75 years ± 2.67) met the inclusion criteria and were randomized to either the fatigue or non-fatigue groups. The fatigue group included 11 individuals (4 females and 7 males) while 13 participants were allocated to the non-fatigue group (3 females and 10 males). The sample size of 24 participants was powered based on prior lower extremity research demonstrating significant between group differences when comparing fatigue to non-fatigued testing of the Lower Quarter Y-Balance Test (YBT-LQ).[14]

Procedures

The protocol described by Gorman et al[5] was utilized for YBT-UQ testing procedures with the Y-Balance Test kit (Functional Movement Systems, Chatham, VA). Prior to conducting the initial testing procedures all participants viewed a video on proper performance of the test, received a demonstration by the primary investigator and practiced two trials in all

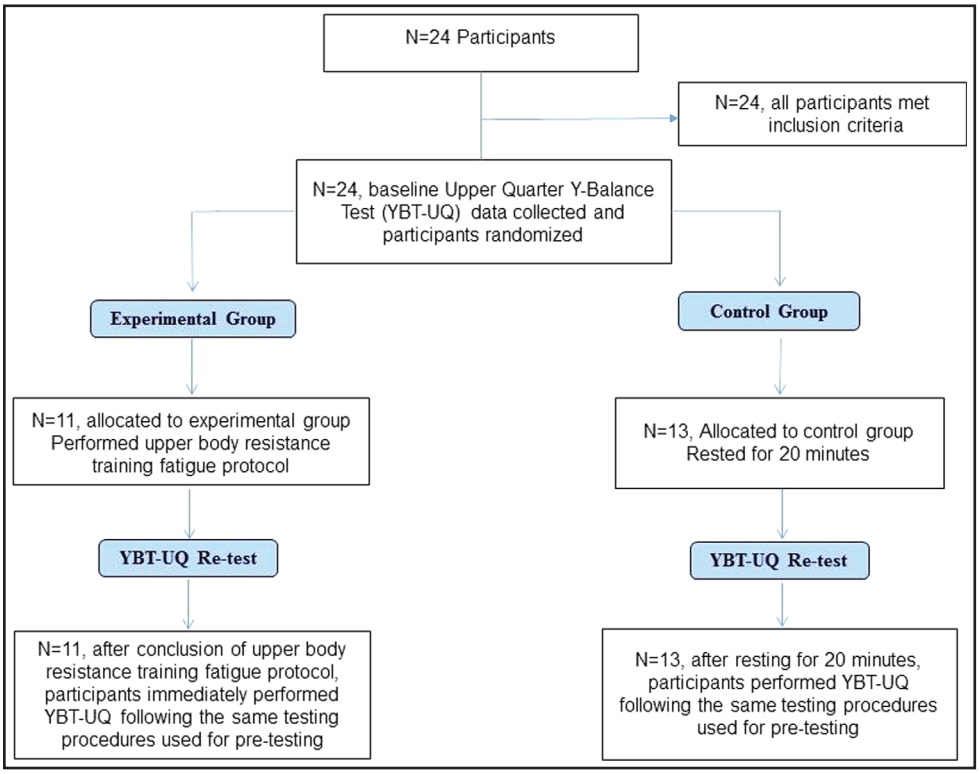

Figure 1. *Diagram outlining the flow of both the control and fatigue groups of subjects.*

three directions on both the right and left limb prior to actual testing. The right arm was then measured from the 7th cervical vertebrae to the tip of the middle finger with the shoulder in 90 degrees of abduction. Participants were asked to reach as far as possible in all three directions and the distance for all three trials in each direction were recorded (Figure 2). Consistent with the calculation used by Westrick et al.[6], reach distance was calculated for each direction by taking the average of the three attempts, dividing by right upper extremity limb length, and multiplying by 100. A composite score was also calculated by taking the sum of the average reach distance in each of the three directions and dividing it by three times right upper extremity limb length.

Participants randomized to the experimental group performed a fatigue protocol under the guidance of research assistant blinded to YBT-UQ scores. The overhead shoulder press (Figure 3) and seated row (Figure 4) were performed at the participants 10 repetition maximum for each exercise. The prone push-up (Figure 5) and pull-up (Figure 6) exercises were each performed to failure. A 30 second rest was utilized between each exercise with a 90 second rest provided at the conclusion of all four exercises. Three sets of each exercise were performed in total prior to immediately re-testing the YBT-UQ.

Participants who were assigned to the control group were asked to rest in a seated position for 20 minutes in a separate room. Examiners were blinded to participant allocation for the fatigue protocol or resting protocol. Following the completion of the resistance training protocol or rest protocol, participants were re-tested on the YBT-UQ using the same procedures as previously described. Examiners were blinded to group allocation for each individual participating in this study.

Data Analysis

The statistical package for social sciences (SPSS version 22.0, Chicago, Ill.) was used for analysis. Baseline between group differences for demographic data including height, weight, body mass index, arm dominance and age were compared with the independent samples *t* test. The two-way factorial Analysis of variance (ANOVA) was used to compare the interaction between group and time to analyze both between and within group differences for YBT-UQ

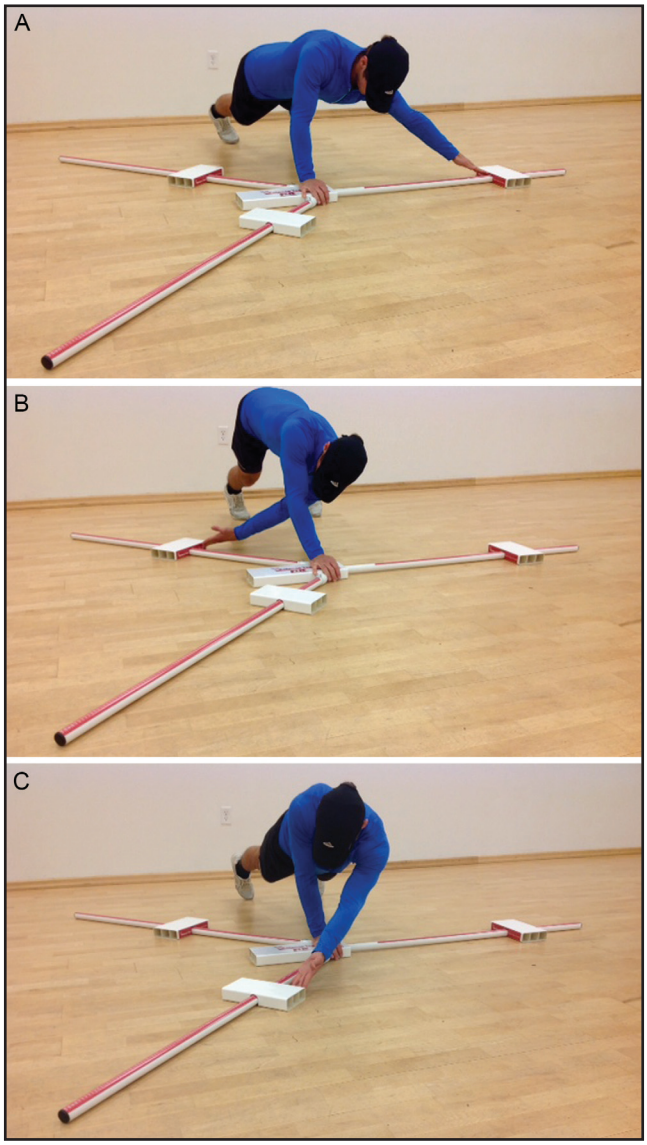

Figure 2. *Performance of the YBT-UQ test in each of the three reach directions; a. medial, b. inferolateral, c. superolateral.*

Figure 3. *Overhead machine shoulder press exercise performed to 10 repetition maximum as a part of the upper body fatigue protocol.*

Figure 4. *Seated machine row exercise performed to 10 repetition maximum as a part of the upper body fatigue protocol.*

scores. Separate ANOVA's were conducted to examine each direction therefore a Bonferroni corrected alpha ($p = .05/3 = .016$) was utilized.

RESULTS

Descriptive characteristics of all subjects are presented in Table 1. The pre- and post-test results for the mean and standard deviation score for each direction are provided in Table 2. Table 3 presents pre- and post-test results for the composite score while Figure 7 compares post test scores in the fatigue and control group. The fatigue protocol resulted in a significant reduction in YBT-UQ scores in comparison to the non-fatigue protocol when analyzed by the interaction between group and individual directions ($p \leq .006$) and composite scores for both limbs ($p < .035$). The reduction in scores for the fatigue group ranged from 2.04cm – 12.16cm for both limbs, individual reach distances and composite scores, indicating that fatigue significantly impairs testing scores on the YBT-UQ.

DISCUSSION

Upper extremity injuries are common in both sport and recreational activities. However, few closed

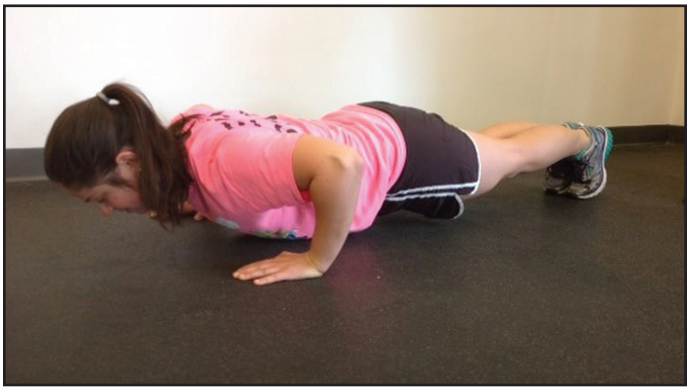

Figure 5. *Prone push-up exercise performed to failure as a part of the upper body fatigue protocol.*

kinetic chain tests have been identified to assess those with upper extremity performance deficits prior to returning to sport. Moreover, even fewer studies have examined the effect of fatigue on the performance of these upper quarter closed kinetic chain tests. The YBT-UQ has previously been identified as a reliable assessment of unilateral upper extremity closed kinetic chain excursion ability in healthy college-aged subjects.[5,6] The purpose of the current study was to identify if upper body fatigue affected the performance on the YBT-UQ. The results of the current study suggest there is a significant decrease in YBT-UQ performance when performed in a fatigued state.

Previous researchers have found similar reach distances normalized to limb length in a variety of populations when performing the YBT-UQ in a non-fatigued state.[5,6,15,16] Taylor et al[17] reported YBT-UQ reach distances in Division 1 collegiate athletes, which in comparison to the current study reach distances, were in excess of 10cm greater in each direction. This difference in excursion is likely a result of the different populations tested; Division 1 athletes vs. recreational weightlifters.

Figure 6. *Pull-up exercise performed to failure as a part of the upper body fatigue protocol.*

To the authors' knowledge, no other studies have examined the impact of a rested and fatigued state on UQ-YBT scores, nor on other tests of closed kinetic chain upper quarter function (CKCUEST, one-arm hop test). Therefore, it would be challenging to directly compare these results against other studies of upper quarter functional testing under fatigue. The results of this study can be compared to other studies that have examined the role of fatigue on movement and performance.

Table 1. *Descriptive characteristics for both the fatigue and non-fatigue groups.*

Subject characteristics	Non-fatigue (n=13, 3 males, 10 females)	Fatigue (n=11, 4 females, 7 males)	p-value*
Age (yrs)	26 (1.41)	25.45 (3.72)	.061
Weight (kg)	80.18 (14.33)	78.59 (13.45)	.651
Height (cm)	175.94 (9.22)	178.03 (10.98)	.437
Right limb length (cm)	89 (4.84)	87.18 (6.00)	.567

Reported as mean ± (standard deviation)
*Independent samples *t* test

Table 2. *Comparison of pre- and post-testing scores examining the interaction between group and time with the factorial ANOVA for the right and left limbs. Reported as mean ± (standard deviation).*

YBT-UQ direction	Non-fatigue group pre-test (n=13)		Non-fatigue group post-test (n=13)		Fatigue group pre-test (n=11)		Fatigue group post-test (n=11)	
	Right	Left	Right	Left	Right	Left	Right	Left
Medial	97.05 (8.22)	99.76 (8.04)	98.10 (8.84)	101.51 (8.65)	100.74 (4.83)	100.55 (5.69)	96.11* (5.86)	98.51* (7.59)
Superior /lateral	68.33 (10.78)	69.60 (11.39)	68.36 (9.97)	70.89 (10.93)	65.58 (5.86)	67.18 (7.06)	55.50* (8.54)	55.02* (8.32)
Inferior /lateral	92.37 (11.20)	85.84 (10.80)	94.72 (11.40)	87.05 (9.54)	95.56 (7.51)	87.48 (6.35)	87.55* (8.75)	79.98* (8.57)

*Significant at p<.016

Table 3. *Comparison of pre- and post-testing composite scores examining the interaction between group and time with the factorial ANOVA for right and left limbs. Reported as mean ± (standard deviation).*

YBT-UQ	Non-fatigue group pre-test (n=13)		Non-fatigue group post-test (n=13)		Fatigue group pre-test (n=11)		Fatigue group post-test (n=11)	
	Right	Left	Right	Left	Right	Left	Right	Left
Composite Score	85.92 (9.06)	85.07 (9.45)	87.06 (8.78)	86.48 (9.09)	87.29 (3.85)	86.72 (4.89)	79.72* (4.65)	77.83* (6.10)

*Significant at p<.035

Fatigue has been demonstrated to result in a reduction of muscle force, impaired coordination, delayed neuromuscular activation, and impaired joint stability.[8-13] It has also been shown previously that a significant portion of injuries occur in the latter stages of games/competition, which indicate a potential effect of fatigue on risk of injury.[18-20] Sarshin et al[12] demonstrated a reduction in dynamic postural control, measured by YBT-LQ excursions, after fatigue was induced via running at different intensities. Similarly, Wassinger et al[21] found that distant fatigue, or fatigue induced at a different area of the body being tested, can also impact performance as subjects in their study performed an upper body fatigue protocol resulting in a decrease for dynamic standing balance measured via the YBT-LQ. In a systematic review, Santamaria and Webster[9] found fatigue appears to affect lower-limb biomechanics during single-limb landings.

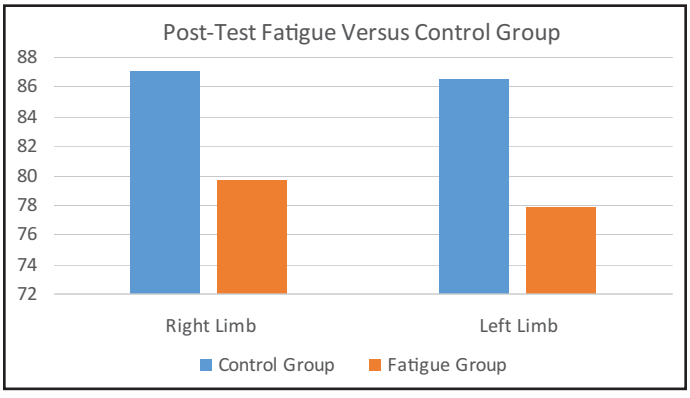

Figure 7. *Fatigue group and control group comparison of post testing composite YBT-UQ scores for both right and left limbs.*

Study limitations include limited generalizability outside of the recreational weight training population and use of an exercise protocol that may create a level of fatigue excessively specific to the upper quarter. An effort was made to utilize a fatigue protocol specific to recreational weight lifters but this may not be applicable to athletes engaging in other sports or recreational activities. A comparison for both local muscular and aerobic fatigue should also be considered, as this investigation did not monitor energy expenditure or correlate levels of fatigue to YBT-UQ scores.

Future research involving the use of YBT-UQ should be performed in specific athletic populations and utilize a fatigue protocol that closely simulates the demand of the sport for the population being studied. Performing a fatigue protocol that closely resembles the physiological demand of the sport or activity allows for the potential of combined local

and central responses specific to that sport. Future research should also examine a fatigue protocol targeting the trunk and lower extremity musculature due to the YBT-UQ not specifically being an isolated upper extremity test. There is also a need to expand normative data using the YBT-UQ on varied populations. Additionally, there is a need to expand data of YBT-UQ performance both in a rested and fatigued state to determine if differences exist among populations other than the recreational weightlifter population used in this current study.

CONCLUSION

The performance of an upper body fatigue protocol significantly reduces YBT-UQ scores in recreational weightlifters for all three individual reach directions and composite scores. Clinicians using the YBT-UQ for return to activity decisions should be aware of the individuals' state of fatigue during testing. Additionally, clinicians should consider testing in both a non-fatigued and fatigued state to allow for a more thorough evaluation of performance prior to return to activity.

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